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TO: Mr. J.E. MITCHELL
Manager
Technical Services and Development Department
Program Support and Services Division
C25F6

OPPORTUNITIES FOR ELECTROTECHNOLOGIES: CURING APPLICATIONS IN ONTARIO INDUSTRY

S.J. Oda

A review of published material on electrotechnologies for industrial curing applications has identified promising opportunities for new marketing and research and development initiatives. This report contains an overview and an appendix that details the rationale for the selection of these opportunities.

INTRODUCTION

Electric curing technologies like infrared, ultraviolet, electron beam and microwave offer significant process benefits that are well recognized. In Ontario, a number of curing opportunities are available to utilize the special characteristics of electrotechnologies for customer benefit. The opportunities that are described in detail in Appendix 1 provide a basis for Ontario Hydro to focus its efforts through technology transfer and further research and development.

OVERVIEW

The study identified 53 curing processes that are tabulated in a matrix of curing application versus industry segment (see Appendix 1). From the matrix entries technology transfer and further R&D opportunities were selected based on customer benefit as well as economic and industry health factors. A project summary sheet at the beginning of the appendix lists these applications and provides an Ontario Hydro perspective of the study.

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Product curing by electrotechnologies will have **no significant load impact** on Ontario Hydro in the future. In fact, because process time can be significantly reduced, **electrical demand and energy reductions are possible** based on the decrease in electricity use for conveyors and fan drives alone. For example, in rubber vulcanization, microwave systems require about 30% less direct electricity requirement than conventional electrically-heated salt-bath methods because of the speed of throughput. In another example, where ultraviolet curing replaces the more traditional electric infrared equipment, electric demand reductions on the order of 60% may be expected.

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Approved by:

A.F. Baljet
Manager
Electrical Research Department

Submitted by:

S.I. Oda
Senior Utilization Engineer
Utilization Section

APPENDIX 1

Opportunities for Electrotechnologies:

Curing Applications in Industry

PROCESS APPLICATION REPORT SUMMARY

SUBJECTS

Curing / microwave / radio-frequency / infrared / ultraviolet / electron beam / productivity

TOPICS

Electrotechnology / customers - industry / process / curing

AUDIENCE

Industrial customer service and marketing personnel

Opportunities for Electrotechnologies: Curing Applications in Ontario Industry

Electric curing technologies offer significant process benefits that are well recognized. In Ontario, a number of curing opportunities are available to utilize the special characteristics of electrotechnologies for customer benefit. This study provides a basis for Ontario Hydro to investigate these opportunities through technology transfer and further research and development.

BACKGROUND

The application of electrotechnologies in Ontario industry is becoming more widespread for various reasons including better process control, improved product quality, increased production rates and lower operating costs. By helping to improve the productivity and competitive position of the manufacturing sector, electrotechnologies are an important tool that will continue to enhance the health of the Ontario economy. This document, second of a series of four reports, describes technology transfer and research and development opportunities in curing. Other reports describe opportunities in drying, non-metallic heating and heat recovery using electrotechnologies.

OBJECTIVE

To identify, analyze and report through an extensive review of published overview documents, significant opportunities for electrotechnologies in curing processes.

APPROACH

Published material was acquired from a number of sources including EPRI, the Gas Research Institute (GRI), Ontario Hydro (Research Division and Product Knowledge Centre), the Canadian Committee on Electrotechnologies (CCE), the International Union for Electroheat (UIE) and the Canadian Electrical Association (CEA). Using documented findings from these sources, a comprehensive matrix was assembled to summarize the information. Selection criteria were applied to the matrix entries to target a particular application for technology transfer or further research and development. All of the applications were required to provide undeniable benefit(s) to the customer. In addition, the selection criteria also considered replication potential in Ontario, possible energy/demand reductions, environmental benefit(s), and the overall health of the industry.

RESULTS

This study reviewed over 80 key documents from which 53 curing processes were identified and tabulated in a matrix of curing application versus industry segment. The matrix contains curing processes in all major industry segments in the following categories: application description; current technology (if not electric); electrotechnology alternative; limitations of the electrotechnology; identification of an electrotechnology commercialized elsewhere but not in Ontario (technology-transfer needs); unresolved problems or questions requiring answers before technology transfer can take place (R & D needs); potential for replication in Ontario; key literature references describing the application; and, trade allies (eg, companies, industry and university research organizations) for possible future collaboration.

This study identified the following technology transfer opportunities: curing coatings on electrical wire using ultraviolet light; microwave preheating and vulcanization of rubber; ultraviolet curing of ink in book, newspaper, periodical and package production; curing electrostatically applied powder coatings on metal products with infrared radiation; ultraviolet curing of composition board coatings.

The following research and development opportunities were identified: curing ink and overcoat varnish on cans using ultraviolet radiation; electron beam processing of wood pulp chips.

ONTARIO HYDRO PERSPECTIVE

The corporate goal of improving the energy efficiency of Ontario industry requires an understanding of the growth potential and subsequent load impact that electrotechnologies will produce over the next fifteen years. Curing, in industrial processes, is dominated by natural gas-fired technologies. The amount of electricity used in industry for both drying and curing applications is less than one fortieth of the natural gas used for the same purpose. Curing electrotechnologies will be restricted to niche application areas where there are significant benefits to the industrial customer. These applications, while numerous, will have minimal load impact on Ontario Hydro in the future. In fact, because process time is sometimes significantly reduced with a resultant reduction in electricity use for conveyors and fan drives, net electricity use reductions are possible.

This project, which looks at the use of electrotechnologies for curing in Ontario industries, shows that growth is occurring as Ontario industry struggles to maintain its competitive position in the world marketplace. As this study shows, there are a number of opportunities for applying electrotechnologies in industrial curing processes that lead to undeniable benefits for the industrial customer. A matrix of curing applications and electrotechnologies is provided from which a short list of curing opportunities is extracted to target both technology transfer and further research and development. This document will help industrial customer service representatives (to become more familiar with curing electrotechnologies and help their customers optimize energy use for curing operations); and, industrial technology and products staff and market planners to understand what the current and future potential is for curing electrotechnologies in Ontario industry.

PROJECT TEAM

S.J. Oda, Utilization Section
R.L.D. Cane, B.E Sibbitt, D.A Forgas, Caneta Research Inc.,
M.R. Sanio, Industrial Technology & Products Section

Opportunities for Electrotechnologies:

Curing Applications in Industry

May 1990

Prepared by

Caneta Research Inc.
6981 Millcreek Dr., Unit 28
Mississauga, Ontario L5N 6B8

and

S.J. Oda
Utilization Section
Electrical Research Department
Research Division
Ontario Hydro
800 Kipling Avenue, KR263
Toronto, Ontario M8Z 5S4

Prepared for

M.R. Sanio
Industrial Technologies and Products Section
Technical Services and Development Department
Program Support and Services Division
Ontario Hydro

ABSTRACT

An extensive review of published material on electrotechnologies for industrial processes has been undertaken to identify promising applications for new marketing or research and development initiatives. The processes included in this review are drying, curing, heating of non-metallic materials and heat recovery. This report presents the rationale for the selection of seven promising curing opportunities for future technology transfer and research and development projects.

TABLE OF CONTENTS

1.	INTRODUCTION		10
	1.1	Background	10
	1.2	Objective	11
	1.3	Method of Approach	11
2.	CURING APPLICATIONS		13
	2.1	Energy Use in Curing	13
	2.2	Reasons for and Methods of Curing	14
	2.3	Benefits of Electrotechnology Curing Processes	15
	2.4	Limitations of Electrotechnology Curing Processes	16
	2.5	Selection of Curing Applications for Future R & D and Technology Transfer	17
3.	PROMISING CURING APPLICATIONS		20
	3.1	Technology Transfer Opportunities	20
		3.1.1 Curing Powder Coatings	20
		3.1.2 Curing of Ink	21
		3.1.3 Preheating and Vulcanization of Rubber	22
		3.1.4 Curing of Wire Coatings	22
		3.1.5 Curing Composition Board Coatings	23
	3.2	Research & Development Opportunities	24
		3.2.1 Curing Coatings on Cans	24
		3.2.2 Processing Wood Pulp Chips	25
4.	CONCLUSIONS		26
5.	RECOMMENDATIONS		28
6.	REFERENCES		29
APPENDIX A		Curing Applications in Industry	A-1
APPENDIX B		UV Materials and Equipment Suppliers	B-1

LIST OF FIGURES AND TABLES

Figure 1	Ranking of Industries with Curing Opportunities	19
Table 1	Health of Industrial Sectors with Curing Opportunities	A-1
Table 2	Summary of Curing Applications in Industry	A-2
Table 3	Food Industries	A-3
Table 4	Rubber Products Industries	A-5
Table 5	Plastic Products Industries	A-6
Table 6	Wood Industries	A-7
Table 7	Paper and Allied Products Industries	A-9
Table 8	Printing, Publishing and Allied Industries	A-12
Table 9	Primary Metal Industries	A-14
Table 10	Fabricated Metal Products Industries	A-15
Table 11	Chemical and Chemical Products Industries	A-17
Table 12	Electric and Electronic Products Industries	A-18
Table 13	Miscellaneous Industries	A-22

1 INTRODUCTION

For various reasons such as better process control, improved product quality, requirements for lower temperature, increased production rates and lower operating costs, electrotechnologies are seeing and will likely continue to see increased application in Ontario industry in various processes such as curing, drying, heating of non-metallic materials and in heat recovery.

1.1. Background

While a significant amount of published material exists, from various sources, on the subject of industrial electrotechnology application, there was a need to synthesize, analyze and organize the key information into a format which would be useful to Ontario Hydro for planning both marketing initiatives and research and development projects. Studies were funded by the Technology Services and Development Department of Ontario Hydro, to identify opportunities for drying, curing, non-metallic heating and heat recovery in Ontario industry.

It was intended that the investigation identify electrotechnologies being used elsewhere in promising applications where Canadian application was currently limited. It was also expected that promising applications would be identified which would require further research and development before market introduction. While the main criteria for selection or targeting of a particular application for technology transfer or further research was the undeniable benefit(s) which imply technical and economic feasibility to the industrial customer, other criteria, of varying importance were considered. These are as follows:

* Replication Potential (i.e. as a first approximation, the number of plant sites in Ontario within the same industry classification);

* Energy/Demand Reductions;

* Environmental Benefit;

* Trade Allies (ie. outside organizations, whether they be industry associations or involved in research and development, with interest in promoting or co-sponsoring the development of a particular application or have work in progress which could benefit Ontario Hydro and its industrial customers);

* Industry Health (e.g. particular interest in fast growth industries and industries of significant size capable of investing or compelled to invest in new technologies).

The targeted research projects, wherever possible, were to build on the expertise of the Process Applications Laboratory of Ontario Hydro's Research Division Process Applications Laboratory. Over the past 5 years, this group has gained a great deal of practical experience in product processing. They understand where, how and when to apply electrotechnologies to achieve the best results for the industrial customer. New opportunities to apply the existing capabilities and facilities of the Process Application Group, in co-funded research and development projects, in collaboration with other universities or research institutes were to be sought.

The scope of the investigation was to identify promising applications for electromagnetic radiation technologies (microwave, radio-frequency, infrared, ultraviolet, electron beam) and electrically-driven, vapour compression equipment (open and closed-cycle) in curing, drying, non-metallic heating and heat recovery processes.

1.2 Objective

To identify, analyze and report, through an extensive review of published overview documents, significant opportunities for electrotechnologies in drying, curing, non-metallic heating and heat recovery processes.

1.3 Method of Approach

The search for published material of relevance was undertaken on three fronts. The Electric Power Research Institute (EPRI) Guides and the Gas Research Institute (GRI) Published Research Report directory were reviewed to identify key, overview documents, prepared by these organizations on the industrial processes of direct interest to the study. Those reports not held by Caneta, Ontario Hydro were ordered by the Product Knowledge Centre, Technology Services and Development Department, Ontario Hydro.

Additional published material was identified through the Canadian Committee on Electrotechnologies (CCE), the International Union for Electro-Heat (UIE) and the Canadian Electrical Association (CEA) and obtained for in depth review and analysis. Energy use statistics and Standard Industrial classification (SIC) data for industry were obtained from the Ontario Ministry of Energy and Statistics Canada. These statistics would be used to identify appropriate SIC codes for interesting electrotechnology applications. The same data also provided an indication of the importance of energy cost in a particular industrial segment, the size of the industry (value of shipments) and the number of establishments in Ontario.

Over 80 research reports, technology transfer documents and technical articles were identified and are listed in Chapter 6, References. From these references, the key documents were identified following an initial review and information of direct relevance to the particular process was documented. The information needed to assess the opportunity, for a particular application includes the following:

* Description of the Application;
* How was the application currently done in industry?;
* What Electrotechnology is used to perform the same task? What is the industrial application status of the electrotechnology?;
* What are the limitations of the electrotechnology compared to the current technology?;
* Are there unresolved problems or questions which need to be answered? What are the R & D needs?;
* Are there applications already in-place elsewhere? What are the Technology Transfer needs?;
* What is the potential for replication in Ontario (ie. number of similar establishments in Ontario suitable for the same application?);
* Key References in the literature describing the application;
* Trade Allies for future collaboration.

Finally, individual, process-oriented reports on drying, curing, non-metallic heating and heat recovery were to be prepared were to be prepared which would present the full range of applications identified, the rationale for targeting of specific applications for future research or technology transfer efforts, and the R & D and technology transfer opportunities.

This report presents the opportunities for curing applications in Ontario industry using electromagnetic radiation technologies.

2 CURING APPLICATIONS

Curing in this report refers to processes in which the physical or chemical nature of the polymeric material being acted on is changed (eg. vulcanization of rubber). For this document the definition of curing has been extended to include processes that kill spoilage-causing organisms in leather, food and wood. While coatings may be either cured or dried both types of processes are included here since they involve common industry groups and trade associations.

2.1 Energy Use in Curing

Total manufacturing energy use in the United States was estimated [26] to be 3400 terawatt-hours equivalent in 1985. Of this total, 2300 terawatt-hours equivalent were for process heating. Natural gas accounted for about 45 percent of this total or 1020 terawatt-hours. Natural gas consumption for baking, drying and curing operations [26] was equivalent to about 220 terawatt-hours used in process heating applications in manufacturing industries.

On the other hand, the **total** use of electricity in process heating [26] was estimated to be only 60 terawatt-hours or about 3 percent of the total. Of this, only 5.5 terawatt-hours was consumed in electric drying and curing applications. As a comparison, the electrical energy consumed by motors, in the manufacturing sector [26], was 508 terawatt-hours, or two orders of magnitude greater.

A study for Ontario Hydro in 1985 [1] estimated process heating energy consumption in Ontario to be 40 terawatt-hours. Electricity use for process heating was estimated to be 0.75 terawatt-hours, or about 2 percent of the total. This compares favourably with the 3 percent estimated for the United States [26]. While data on electric curing energy use could not be found for Ontario, a similar penetration to that shown in the U.S. data is anticipated. It can therefore be concluded that curing and drying processes are predominantly fossil-fuel based and will likely continue to be so. The exceptions will be processes where electrotechnologies offer significant benefits to the industrial customer. While there are many industries with curing opportunities for electrotechnologies, the load impact will likely be minimal.

Recent data published by EPRI [26] estimated the electricity consumption of electrotechnologies in various industry categories. Infrared processing was estimated to account for about 2.3 terawatt-hours of electricity use in 1985. While ultraviolet curing and electron beam processing used 0.9 terawatt-hours and 0.14 terawatt-hours respectively. In total, this electricity consumption represents only about 2 percent of the total consumption by all electrotechnologies in the United States. This data supports the earlier statement that the electrotechnologies investigated here are likely to have minimal load impact on Ontario Hydro in the future.

Many electrical curing applications consume less energy than the competing technologies. In some cases electrical demand may be reduced when a more efficient electrotechnology replaces another (eg. UV versus IR curing of composition board coatings). Reduced demand may also result when shorter line length, reduced material handling, lighting and/or space conditioning (including ventilation) requirements have a greater impact than the process energy use itself.

2.2 Reasons for and Methods of Curing

The curing process is generally used to contribute to a desired set of properties in a product. It can for example: add toughness, dimensional and thermal stability to three dimensional products; provide attractive, hard and chemical-resistant finishes on paper, wood and metallic substrates; set adhesives; transform materials (eg. ink from liquid to solid or powder to coating film); and impart memory to textiles (ie. heat setting). In this report the definition of curing has been extended to include applications involving the elimination of micro-organisms or insects, generally to improve the safety and shelf-life of the products.

Curing in industry is usually accomplished with fuel-fired convection ovens, heated rollers or platens, hot-air fluidized beds, room temperature air and chemical processes. The electrotechnologies discussed here involve electromagnetic radiation-curing sometimes in conjunction with conventional thermal ovens. The forms of radiation energy include electron beam (EB), ultraviolet (UV), infrared (IR), microwave (MW) and radio-frequency (RF) wavelengths.

A total of 53 processes involving curing were identified in the review of the technical literature. While not necessarily exhaustive, the processes summarized in the Curing Applications in Industry matrices in Appendix A cover all major industry segments except Tobacco Products, Machinery Industries and Refined Petroleum & Coal Products. Each process is described and information provided where available, on benefits, limitations, R & D and technology transfer needs and replication potential in Ontario, for each electrotechnology application.

2.3 Benefits of Electrotechnology Curing Processes

Electromagnetic radiation in the radio-frequency (13.56, 27.12 and 40.68 MHz) and microwave (915 and 2450 MHz) bands may be used to heat non-metallic or dielectric materials through the vibration of polar molecules and/or ionic conduction. In curing processes the microwave (MW) and radio-frequency (RF) technologies provide benefits such as uniform heating, more efficient heating particularly when the volume-to-surface area ratio is large, increased production rates, more compact equipment, improved product quality (often due to better control of the process), energy savings and elimination of some pollution problems. The ability of radio-frequency and microwaves to penetrate and add heat throughout a solid volume is usually of prime importance in applications to which these technologies are ideally suited.

Infrared radiation is the wavelength band of the electromagnetic spectrum from about 1 to 400 microns. Materials such as textiles, paper, paints, other coatings and water readily absorb energy in the infrared range within thousandths of a centimetre of the surface. Infrared radiation is therefore ideal for certain curing applications, particularly where thin films or coatings are being processed. Electric infrared equipment is also claimed to provide increased production rates, lower capital and operating costs and cleaner product than conventional hot air processes. Electric infrared equipment often competes against gas-fired infrared which may put it at an operating cost disadvantage in areas where natural gas is available. However, electric infrared is claimed to have lower first cost, result in a cleaner product and better working conditions, produce higher power densities and provide more precise process control than natural gas-fired infrared.

Ultraviolet (UV) radiation is that part of the electromagnetic spectrum with wavelengths between 4 and 400 nanometres. Typically generated with a mercury vapour lamp, UV radiation causes photochemical or photopolymerization reactions to take place in the radiation absorbing material, with the result being a fully cured, cross-linked solid coating or film. Ultraviolet curing is used primarily in coating applications such as in decorative finishes, insulating films or curing of printing inks. Relative to standard coatings and conventional thermal ovens, UV coating systems are claimed to eliminate volatile emissions, result in improved product properties, allow increased production rates and the finishing of heat sensitive substrates with lower capital and operating costs while using less floor space. Ultraviolet curing is an efficient process that usually offers energy savings relative to conventional thermal processes as well as a reduction in electrical demand relative to electric IR curing.

An electron beam (EB) is generated by heating a cathode to produce free electrons, accelerating these electrons through an anode with a high DC voltage field and directing and focusing them electromagnetically. To avoid scattering the beam with air molecules a vacuum is maintained throughout most or all of its length. Electron beam is considered to be ionizing electromagnetic

radiation in the wavelength band 10^{-3} to 10^{-1} nanometres. EB curing is claimed to result in improved product properties, high processing speeds, low processing temperatures and reduced operating costs. While extensive shielding is required to contain X-rays generated by the high energy electrons impinging on dense materials in their path and first costs tend to be high, some processes are currently not possible without high energy radiation processing. Additional technical information on curing electrotechnologies can be found in several references [17,20,24,26,27,35,47,61,64,68,69,81].

2.4 Limitations of Electrotechnology Curing Processes

Microwave equipment generally has a higher capital cost than conventional heating equipment, an intermediate energy conversion efficiency, with over-all efficiency dependent on the product's dielectric properties, its shape and size. RF equipment, while having a lower capital cost than microwave equipment, is better suited to applications where the product has a regular shape with large dimensions and a high dielectric loss factor. Due to capital cost considerations, microwave equipment is restricted to relatively low applied power applications, normally less than 50 kW capacity.

Infrared equipment is best used in line-of-sight applications where the material being cured is on surfaces which are repetitive and simple in form and shape. Where applications call for a combination of forced-air and infrared equipment, gas-fired will often be the choice simply because natural gas is already used in most forced-air heating equipment.

Ultraviolet curing processes require the use of coating materials and inks that are formulated to react with the UV radiation. While the cost of these materials is typically 2 to 3 times the cost of their thermally cured counterparts, reduced number and thickness of coats tends to compensate. The acceptance of UV processes may be limited by the perception that they are more complex and less forgiving than thermal ones.

Electron beam technologies require very high plant utilization to justify the high capital cost of the equipment which is typically 60% greater than for conventional thermal ovens or approximately 5 times that for UV systems[1]. Shielding to contain X-rays and the requirement for an inert atmosphere are added complexities that limit use of EB technologies to applications where there are distinct benefits. Radio isotopes such as Cobalt-60 provide the major competition for EB processors.

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[1]Based on several case studies [24].

2.5 Selection of Curing Applications For Future R & D and Technology Transfer

The information needed to properly assess the opportunity for various electrotechnology applications was presented in the introduction. The matrices in Appendix A contain information gathered during the review of the literature or contributed by the project team members. In many cases, the information needed to provide a balanced or thorough assessment of a particular curing application could not be found. In some cases, the project team would have liked more information on which to base the selection of targeted applications.

The most important criteria, for selecting promising curing applications, was seen as the undeniable customer benefits. These factors vary from one electrotechnology application to another but generally involve one or more of the following:

- reduced material waste;
- increased process capacity or throughput;
- compact, high power density, significant space savings;
- improved product quality eg. greater safety or shelf-life for food products;
- elimination of a full-time operator with the attendant labour cost reduction;
- reduced risk of fire.

Many of these customer benefits result in clear technical and economic benefits to the industrial customer, often with payback periods less than one year. In addition to those benefits, some applications also promise significant energy/demand reductions in curing processes or an environmental benefit. The latter is becoming more important in day-to-day corporate decision making.

Finally, a promising application's replication potential and the targeted industrial sector's health must be considered. Only where a significant number (or size) of industrial sites is known to exist, which meet the requirements of the application, can Ontario Hydro justify the resources to target R & D activities or encourage replication through technology transfer. In consideration of industry health, applications in large Ontario-based industries or ones experiencing rapid growth are particularly attractive to target. Table 1, Appendix A, presents industry sector data which was used to evaluate an industry sector's attractiveness for targeting promising curing opportunities.

Only those Ontario industry sectors with identified curing opportunities for the electrotechnologies examined are presented in Table 1. The ranking in Table 1 is in descending value of shipments of goods (basis year 1986), with other measures of industry health shown, such as: value-added, growth in electricity used, number of establishments and intensity of value-added.

Figure 1 shows the ranking of these industries against different criteria. For example, the Motor Vehicle Industry is the largest, by far, in value of Shipments of Goods, followed by Meat and Meat Products, Other Food Products, Newspapers, Magazines and Periodicals and Other Plastic Products to round out the top five. Electronic Computers and Peripherals ranks sixth followed by Major Appliances, Communications, Energy Wire and Cable, Metal closure and Container and in 10th place, Aluminum Rolling, Casting, Extruding.

An even more important parameter to consider is value-added within specific industry sectors. This factor is generally a better indicator of a sector's level of manufacturing or processing as opposed to purchasing and passing through the cost of materials. As the value-added increases, an industry will more likely give serious consideration to adopting electrotechnology curing equipment, if there are undeniable benefits. The highest value-added industry in Figure 1 is Motor Vehicle, followed by Newspapers, Magazines and Periodicals, Other Food Products, Other Plastic Products and Meat and Meat Products.
The number of establishments, within a particular industry sector, is also shown in Figure 1. This was used by the project team as a measure of the replication potential for a particular application. However, from a marketing standpoint, the less diverse an industry sector is, the more attractive it would be. Less diverse industry sectors are those with high value-added on a per establishment basis. Industry ranking from this standpoint has been calculated and added to Figure 1 as Intensity of Value-Added. The largest potential, by this measure, exists in targeting promising applications in the Motor Vehicle industry, followed by the Pulp industry and Major Appliances. These three industries have, by far, the highest value-added on a per establishment basis, of those industries with curing opportunities in Figure 1. Fourth is the Steel Pipe and Tube sector followed by the Iron Foundries in fifth.

The undeniable benefits, the replication potential and the industry health factors were all taken into account in the evaluation of the 53 curing applications and the selection of promising curing applications for future R & D and technology transfer activities. The next section briefly describes the rationale for the selection of the applications listed below; the specific R & D and technology transfer needed to encourage their replication in Ontario industry; and, organizations which may be appropriate for collaborative arrangements. The short list of opportunities is as follows:

- Curing Coatings on Cans
- Curing Wire Coatings
- Vulcanization of Rubber
- Curing of Ink
- Processing Wood Pulp Chips
- Curing Powder Coatings
- Curing Composition Board Coatings.

Figure 1 : Ranking of Industries with Curing Opportunities

Intensity* of Value Added

1- *Motor Vehicle*
2- *Pulp*
3- *Major Appliances*
4- *Steel Pipe & Tube*
5- *Iron Foundries*
6- *Communications, Energy Wire & Cable*
7- *Metal Closure & Container*
8- *Aluminum Rolling, Casting, Extruding*
9- *Other Food Products*
10- *Plastic Film & Sheeting*

Number of Establishments

1- *Other Plastic Products*
2- *Other Publishing*
3- *Wooden Household Furniture*
4- *Meat & Meat Products*
5- *Newspapers, Magazines & Periodicals*
6- *Custom Coating of Metal Products*
7- *Electronic Parts & Components*
8- *Other Food Products*
9- *Electronic Computer & Peripherals*
10- *Wooden Door & Window*

Intensity* of Value of Shipments

1- *Motor Vehicle*
2- *Pulp*
3- *Major Appliances*
4- *Steel Pipe & Tube*
5- *Communications, Energy Wire & Cable*
6- *Aluminum Rolling, Casting, Extruding*
7- *Poultry Products*
8- *Cereal Grain Flour*
9- *Metal Closure & Container*
10- *Other Food Products*

Value of Shipments of Goods

1- *Motor Vehicle*
2- *Meat & Meat Products*
3- *Other Food Products*
4- *Newspapers, Magazines & Periodicals*
5- *Other Plastic Products*
6- *Electronic Computer & Peripherals*
7- *Major Appliances*
8- *Communications, Energy Wire & Cable*
9- *Metal Closure & Container*
10- *Aluminum Rolling, Casting, Extruding*

Value Added

1- *Motor Vehicle*
2- *Newspapers, Magazines & Periodicals*
3- *Other Food Products*
4- *Other Plastic Products*
5- *Meat & Meat Products*
6- *Electronic Computer & Peripherals*
7- *Major Appliances*
8- *Iron Foundries*
9- *Metal Closure & Container*
10- *Other Metal Rolling, Casting, etc.*

Growth in Electricity Use (%)

1- *Coated & Treated Paper*
2- *Book Publishing*
3- *Other Metal Rolling, Casting, etc.*
4- *Contract Textile Dyeing & Finishing*
5- *Meat & Meat Products*
6- *Custom Coating of Metal Products*
7- *Communications, Energy Wire & Cable*
8- *Adhesives*
9- *Fish Products*
10- *Other Food Products*

* Intensity = (Value of Shipments or Value Added) / (Number of Establishments)

3 PROMISING CURING APPLICATIONS

Applying the criteria described in detail in section 2, curing applications were selected from the 53 contained in Appendix A. Each of the applications targeted for technology transfer or for research and development are in Ontario industries, which rank in the top ten of two or more of the important criteria shown in Figure 1, with two exceptions.These are Vulcanization of Rubber, for which data was not available, and Curing Composition Board Coatings, which has numerous benefits including electrical demand reduction, in a modestly sized industry. Secondly, the application of the electrotechnology to the specific process offers the industrial customer undeniable technical and economic benefits. In the case of research and development opportunities, while the same industry criteria were applied in the selection process, consideration was also given to the capabilities and facilities within the Process Application Group and the potential for collaboration with other research groups or agencies.

The following sections briefly describe each of these opportunities. For those applications involving further R & D, it is suggested that detailed project descriptions be prepared. An example of a project description is outlined in Appendix B.

3.1 Technology Transfer Opportunities

3.1.1 Curing Powder Coatings

The Steel Pipe and Tube Industry did not rank highly in value of shipments, however, with 20 Ontario establishments, the intensity of value of shipments and the intensity of value added both ranked 4th in industries with curing opportunities, Figure 1. While infrared radiation has been successfully used to cure powder coatings on the inside and outside surfaces of steel pipe and tubing, this industry sector is only one of many where this technology has found application. Other examples of metal products using IR-cured powdered coatings include: electronic parts trays; aluminum cylinders; oil filters; disc brake pad assemblies; appliance components; door hardware, cast aluminum wheels, steel door skins and aluminum window frames. IR-cured powder coatings are also used in coating papers, textiles and plastic films as well as in the application of adhesives.

Steel pipe and tubing would conventionally be sprayed or dipped in solvent based paint which would be dried in a gas-fired oven. Alternately, the use of a powder coating which may be applied using electrostatic spray equipment or by immersing the part in a fluidized bed of suspended powder (which is sometimes electrostatically charged). Paint transfer efficiencies of 95% may be achieved in the latter process while 30-60% is typical of conventional spray application. Infrared radiation is used to rapidly heat then flow (or melt) the powder and cure it into a smooth, high gloss finish. Since the coating powder is a solid there is no solvent to

evaporate, making the process very attractive from an air quality/emissions perspective. Operating costs are reported to be lower as a result of the more efficient heating process; only the coating and the surface of the substrate are heated. Other advantages of IR include reduced floor area requirements and higher production rates. Additional advantages attributed to electric IR over gas-fired IR include a better quality finish, due to the absence of combustion products and strong convection currents, improved controllability and work environment.

Infrared curing of powder coatings is in widespread use in the U.S. and abroad, but application by Ontario industry is believed to be limited. The opportunity exists to collaborate with the suppliers of IR equipment such as A. D. Smart Ltd., Research Inc. and Impact Systems to produce case study material to raise the awareness of the Ontario industry.

3.1.2 Curing of Ink

The Newspaper, Magazines and Periodicals Industry, with 183 establishments, ranked 15th overall in Ontario and fourth in industries with curing opportunities, in value of shipments of goods of own manufacture, in 1986. It is the most important printing industry segment for UV-cured printing ink followed by the Book Publishing Industry. Essentially the same technology is also applied in the Folding Carton and Set-up Box segment of the Paper and Allied Products Industries.

The printing industry uses five major printing processes: letter press, lithography, flexography, gravure and screen print. Conventional inks are thermally cured or air dried but the use of UV radiation processing equipment with specially formulated inks holds significant benefits including: lower purchase price and short-term payback, reduced floor space requirements, lower installation costs, rapid product processing, elimination of special racking/handling, reduced stock wastage, no emissions or odours, reduced energy consumption and when an electric resistance dryer is replaced with UV demand is roughly cut in half. Additional benefits claimed include instantaneous curing between stations in multicolour printing, reduced insurance costs as a consequence of high flash point inks without fire hazard, easy ink clean-up, elimination of bleeding and smearing. The only noted disadvantage appear to be higher ink costs (roughly 270% of the cost of conventional ink per unit volume or 13% higher per unit of product).

UV processing has penetrated the lithographic, silk screen and to some extent the flexographic printing areas. An opportunity exists, however, to increase that penetration through the development of case study material to raise the awareness of the Ontario industry. Possible collaborators include the suppliers of UV processing equipment and materials listed in Appendix C. Quantification of the cost and production rate benefits is a related R & D opportunity.

3.1.3 Preheating and Vulcanization of Rubber

Financial statistics on the Rubber Hose and Belting Industry and the Other Rubber Products Industry are only available when the two are combined into the Rubber Products Industries Group. As such, they do not appear among the industries with curing opportunities, Figure 1. Together the combined value of shipments of goods, of own manufacture, would rank them 15th overall in Ontario, in 1986, when compared with single industries. As a group they have 96 establishments in Ontario.

In the conventional curing process the heat required to induce the cross-linking reaction would normally be supplied by fossil fuel, through steam, hot-air, fluidized bed or liquid (typically metal) heat transfer media. Rather than relying on heat transfer from the surface, microwave energy causes dipole rotation in elastomers and ionic conduction from the interface of carbon particles thereby adding heat uniformly throughout the product. As rubber has a low thermal conductivity, the use of microwave energy can increase production rates by 30-50%. Since the heating is uniform, product quality is improved and the likelihood of overheated areas lower scrap rates result. Uniform heating also means that the rubber flows more readily into the mould reducing requirements for press and mould maintenance. Additional benefits include lower manufacturing costs as a result of reduced space requirements, less material handling, less operating staff and a net energy cost saving despite relatively high electricity costs.

In 1986, it was estimated [17] that the installed microwave processing capacity in Canada and the U.S. was about 2.5 MW with 1.5 MW for vulcanization and 1 MW for preheating. Companies such as Standard Products Inc. and Uniroyal are actively involved in using this technology. With Canadian market penetration estimated to be 58% in the year 2000 there is significant opportunity for the development of case study information on the most successful installations. Potential allies in efforts to transfer this technology to Ontario Industry include Cober Electronics Inc. and Raytheon Company.

3.1.4 Curing of Wire Coatings

The Communications, Energy Wire and Cable Industry, comprised of 31 establishments, ranked 36th over-all in Ontario and 8th among industries with curing opportunities, in value of shipments of goods of own manufacture, in 1986. Thin coatings are applied to either bare or insulated electrical wires to provide insulation or other desired properties such as improved slip, heat resistance, solvent resistance and flame retardance. Magnet wire which is typical of such applications, is conventionally coated with enamel, containing toxic or high boiling point solvents, which is cured or dried in gas-fired ovens with antipollution afterburners. UV-curable coatings can be applied at high line speeds with simple, low-cost equipment and irradiated to form highly cross-linked, tough, flexible films. Solvent emission problems are eliminated, the process is much more

energy efficient and acceptable performance properties are maintained in the coating [24]. The improvement of working conditions is another expected benefit associated with replacement of gas-fired ovens with UV.

A U.S. equipment supplier (Fusion Systems Corp.) believes that while the extent to which UV is currently used to cure wire coatings in industry is very limited, the potential is large. The most successful applications should be sought out and described in technology transfer documents to encourage the appropriate application of this technology by Ontario industry. The opportunity exists to collaborate with the suppliers of the UV equipment and materials in this undertaking. An associated R & D opportunity is the measurement of before and after energy consumption of a gas to UV conversion.

3.1.5 Curing Composition Board Coatings

The Particle Board Industry in Ontario did not rank highly in terms of value of shipments, however, with only 12 establishments the intensity of value added ranked 18th among those industries with curing opportunities. Growth, as estimated by increased electrical energy consumption, was 6% in 1986.

When particle board is finished it typically has a filler coat applied to provide a smooth surface to which a wood veneer or decorative film is laminated and then covered with a clear top coat. In the conventional process gas-fired ovens or IR generators dry solvent based fillers, adhesives and coatings. Ultraviolet radiation and the associated light-reactive coatings allow products to be processed at ambient temperature so that the substrate is not heated and dried out as it is in the conventional thermal process; cooling and rehumidification are, therefore, not required and it becomes possible to finish heat-sensitive materials such as plastics paper or PVC films. Relative to thermally cured coating systems, the UV-processed product exhibits improved quality in appearance,hardness and sanding properties, allows much higher production rates because of the rapid cure (150 vs 60 fpm) produces no volatile emissions and requires significantly less space to manufacture. Energy consumption is reduced significantly relative to thermal processing and where UV is replacing electric IR, demand reductions on the order of 60% may be expected. While UV-processing equipment is frequently shown to be less expensive than thermal ovens and the UV system results in lower product production costs [24], it is not always chosen when new equipment is purchased because it is sometimes viewed as being more complex and less forgiving than thermal processing. UV-processed coating materials are more expensive on a unit volume basis but in this application the required volume per unit product, to achieve a superior surface appearance, is less than for the thermally processed coating, with the result being a net cost saving.

Approximately 100 U.S. wood finishing or manufacturing companies were reported to be using

UV-curable coatings in 1986 but one supplier of UV-curing systems suggested that this market was still in its infancy with further development needed in the coatings technology to accelerate its widespread acceptance. It is anticipated that pressure from environmental protection legislation will drive Ontario industry to replace thermal with UV-curing systems. The opportunity also exists to collaborate with UV materials and equipment suppliers, as listed in Appendix C, to develop case studies on the most successful applications. The resulting technology transfer material should stress the simplicity of the technology as well as the better known advantages of UV-cured wood coatings.

3.2 Research & Development Opportunities

3.2.1 Curing Coatings on Cans

The Metal Closure and Container Industry, with 49 establishments, ranked 38th over-all in Ontario and 9th in industries with curing opportunities, in value of shipments of goods of own manufacture, in 1986. The exterior finish on cans, which are used to package thousands of products from beer to tennis balls, is generally cured in gas-fired pin ovens, in a continuous process handling 800-1400 cans per minute. The combustion products mixed with air come into direct contact with the cans. Energy consumption is about 22 wh/can and a typical oven temperature is roughly 175°C. Reduction in volatile organic compound (VOC) emissions is likely the greatest concern regarding this equipment.

UV ovens can be very much like their gas-fired counterparts except that UV lamps or irradiators are focused so that the can coatings are cured at a rate of up to 1600 cans/minute. Energy consumption is about 0.4 wh/can and VOC emissions are essentially eliminated because there are no organic solvents in UV coatings. Because UV-curing occurs quickly, these ovens are much smaller. Relative to gas-fired ovens: approximately 10% of the floor space is required; capital costs are approximately 30%; maintenance costs 31%; operating labour cost 100%; but ink costs are about 150%. Electricity consumption is essentially equal for the two ovens but of course considerable gas is consumed in the conventional process making total energy use for the UV-system about 2-5% of that for the gas-fired case. The balance between the costs suggests that if emission concerns and floor space costs are ignored, the gas-fired system is economically more attractive at high utilization rates (5360 hours/yr) because of high ink costs. The UV system is more attractive for lower utilization rates because of lower capital costs. Pollution and floor space costs also strongly favour the UV system.

The Adolph Coors Company and the American Can Company utilize UV-cured inks and overprint varnishes in their production of beverage cans. The systems used make use of two completely different coating chemistries. While these two success stories suggest technology transfer efforts are required, the opportunity to achieve widespread implementation of this process also requires

the development of information on the pros and cons of different coating systems, quantification of economic benefits and data on the field performance of UV-cured can coatings. The development of lower cost UV coatings would naturally be a strong incentive for common use of this application. There appears to be little or no research work, on UV-curable coatings, presently being done in Canadian universities but the Journal of Coating Technology and the Association for Finishing Processes of the Society for Manufacturing Engineers appear to be good sources of technical literature on the subject. Equipment and material suppliers, listed in Appendix C are potential collaborators in the development of case study material for technology transfer efforts on this application.

3.2.2 Processing Wood Pulp Chips

While the Pulp Industry itself does not appear in the list of leading Ontario industries for 1986, the size of this industry may have been understated because of the integration of some pulp plants with other related paper industries such as Newsprint, Paperboard, Building Board and Other Paper Industries. The Newsprint Industry, for example, includes a significant number of integrated plants that produce pulp for the manufacture of newsprint [14]. It ranked 14th overall in the province in value of shipments of goods in 1986. The Pulp Industry itself, with 5 establishments ranked second in both intensity of value added and in intensity of value of shipments in the list of industries with curing opportunities, Figure 1.

The production of pulp involves the chipping of wood and the subsequent digestion or breakdown of the chips in a heated chemical solution. Research studies have found that irradiation of the wood chips with high energy electrons prior to their conversion to pulp can reduce their consumption by insects, fungi and other invasive agents and reduce the amount of heat energy required in their conversion to pulp by breaking down some of the cellulosic components [64]. The result should be an improvement in the competitive position of the industry resulting from reduced wastage and lower energy costs. There is apparently no conventional approach used to achieve the same result.

Further research and development is required in determining the optimum radiation dose and dose rate, in improving the understanding of the interaction between radiation and the chemical compounds involved, and in quantifying the resulting benefits to the customer. Initial efforts should be directed at establishing the economic feasibility of the application. The relative competitive position of the electron accelerator technology relative to radiation sources such as Cobalt-60 also needs to be established. AECL, Whiteshell is currently doing research on this application but information on the research program and results are protected by a non-disclosure agreement with an industrial partner. It is likely that Ontario Hydro could participate in this R & D opportunity as either a contributing research agency or as a funding partner.

4 CONCLUSIONS

There are a very large number of potential electrotechnology curing applications within different industrial processes. A total of 53 curing applications were identified by the project team in an extensive review of published overview documents.

Seven curing opportunities were selected on the basis of their benefits to industrial customers, while at the same time taking into consideration the size, financial health and diversity of the particular industry sector in Ontario. This investigation made every effort to identify those electrotechnology curing applications which were most likely to be attractive to the most important industrial sectors in the province. Another consideration was that potential collaborators or co-funding agencies interested in Ontario Hydro plans, be identified.

Wherever possible, research opportunities were selected to compliment the facilities and capabilities of the Process Applications Unit of Ontario Hydro's Research Division.

This study identified the following technology transfer opportunities:

* curing electrostatically applied powder coatings on metal products with infrared radiation;
* ultraviolet curing of ink in book, newspaper, periodical and packaging production;
* microwave preheating and vulcanization of rubber;
* curing coatings on electrical wire using ultraviolet light;
* ultraviolet curing of composition board coatings.

The following opportunities for further research and development were identified:

* curing ink and overcoat varnish on cans using ultraviolet radiation;
* electron beam processing of wood pulp chips.

There were several other industry sectors that would likely realize substantial benefits from the implementation of one of the curing electrotechnologies; however, only the greatest benefit/strongest industry combinations were selected in this study. For example, treatment of some food products with electron beam radiation holds great promise, but uncertainties related to consumer acceptance precluded selection of this application. This technology is already in use in many countries, primarily for treatment of spices, but also for grain and de-boned poultry [83].

Electron beam technology is ultimately expected to become widely used. Similarly, the use of electric infrared radiation in the curing of car body paint has been successfully used in a number of instances [17]; however, competition from gas-fired infrared offers serious competition in many locations [35], suggesting that this application is not necessarily going to find widespread implementation. Several other applications with clear advantages were excluded because economic benefit was not cited in the reference documents. Indepth study of such applications would likely suggest that targeting additional applications would be warranted.

5 RECOMMENDATIONS

1. Based on the identified opportunities, the following approaches are recommended:

   a) For applications involving technology transfer, some confirmation of the size of the opportunity should be performed through a brief market research survey. Based on this verification, information highlighting actual case studies could be prepared and made available to Regional customer energy staff to Ontario-based companies. Equipment suppliers, actual users and other collaborators could be approached to undertake this study.

   b) For the R & D opportunity in curing of can coatings a project description (objective, scope, rationale, level of funding, estimated completion, deliverables, collaborators, etc.) should be prepared. An example of this type of project description is outlined in Appendix B.

   c) For the wood pulp chip processing R & D opportunity the potential for collaboration should be explored with AECL and their industrial partner.

2. For those studies not directly relevant to Ontario Hydro's current corporate goals, unsolicited proposals or 'Request for Proposals' based on defined opportunities could be prepared with external collaborators for possible outside funding (eg. CEA, EPRI, Ministry of Energy - Enersearch Program, Department of Energy, Mines and Resources).

3. Efforts to locate Canadian-based collaborators (eg. university researchers, trade associations, equipment manufacturers) should be continued.

4. An investigation should be initiated to determine which industry groups are best able to afford investment in new electrotechnologies.

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APPENDIX A

CURING APPLICATIONS IN INDUSTRY

SIC CODE	Industry Sector	Value of Shipments of Goods ($'000)	Value-Added ($'000)	Growth in Electricity Use (%)	Number of Establishments	Intensity of Value-Added ($'000/establish.)
3231	Motor Vehicle	21,332,265	3,441,129	14%	15	229,409
1011	Meat & Meat products	2,689,505	590,828	22%	201	2,939
1098	Other Food products	1,863,446	840,476	15%	127	6,618
2841	Newspapers, Magazines & Periodicals	1,379,146	1,028,356	5%	183	5,619
1699	Other Plastic Products	1,293,442	615,564	13%	405	1,520
3361	Electronic Computer & Peripherals	1,156,360	435,543	-12%	91	4,786
3321	Major Appliances	876,369	426,361	-3%	22	19,380
3381	Communications, Energy Wire & Cable	792,968	243,009	18%	31	7,839
3042	Metal Closure & container	753,013	357,239	9%	49	7,291
2961	Aluminum Rolling, Casting, Extruding	748,613	226,780	-5%	33	6,872
2999	Other Metal Rolling, Casting, etc.	744,844	334,968	27%	60	5,583
2711	Pulp	726,159	282,149	-93%	5	56,430
1012	Poultry products	725,305	205,429	1%	35	5,869
1111	Soft Drink	713,339	262,228	-7%	57	4,600
2941	Iron Foundries	634,037	407,985	3%	52	7,846
2921	Steel pipe & tube	609,260	199,854	-3%	20	9,993
3041	Custom Coating of Metal products	593,351	283,084	22%	177	1,599
3352	Electronic Parts & Components	493,078	264,874	8%	171	1,549
2731	Folding Carton & Set-Up Box	488,876	205,262	3%	57	3,601
2839	Other Publishing	478,885	272,229	-1%	317	859
3562	Glass Products (except Containers)	476,277	219,898	-18%	74	2,972
1631	Plastic Film & Sheeting	465,022	199,052	2%	32	6,220
2543	Wooden door & window	371,283	177,386	6%	82	2,163
1051	Cereal Grain Flour	360,032	63,535	14%	20	3,177
2831	Book Publishing	347,461	260,330	44%	76	3,425
2611	Wooden Household Furniture	324,943	175,896	9%	237	742
2791	Coated & treated paper	284,662	124,629	137%	28	4,451
2792	Stationery Paper Products	256,239	121,033	0%	38	3,185
1611	Foamed & Expanded Plastics	230,764	100,519	-18%	48	2,094
2434	Men's & Boy's shirt & underwear	209,906	110,351	-5%	53	2,082
3792	Adhesives	148,888	68,570	18%	24	2,857
1711	Leather Tanneries	128,136	30,595	0%	17	1,800
2592	Particle Board	105,500	42,166	6%	12	3,514
1992	Contract Textile Dyeing & Finishing	47,662	21,728	24%	33	658
1021	Fish products	N.A	N.A	15%	19	-
1521	Rubber Hose & Belting	N.A	N.A	9%	14	-
1598	Other Rubber products	N.A	N.A	-29%	82	-
1829	Other Spun Yarn & Woven Cloth	N.A	N.A	-1%	33	-
2444	Women's blouse & shirt	N.A	N.A	-8%	7	-
2521	Veneer & Plywood	N.A	N.A	0%	18	-
2714	Building Board	N.A	N.A	2%	1	-
2912	Steel Foundries	N.A	N.A	7%	11	-
3993	Floor Tile, Linoleum & Coated Fabric	N.A	N.A	3%	8	-

Table 1 : Health of Industrial Sectors with Curing Opportunities

Table 2 : Summary of Curing Applications in Industry

Food Industries (10)

1- Meat Treatment	(EB)
2- Radappertized Meats	(EB)
3- Grain Disinfection	(EB)
4- Decontamination of Spices	(EB)

Rubber Products Industries (15)

5- Preheating/Vulcanization of Rubber	(MW) & (RF)
6- Vulcanization of Rubber	(EB)

Plastic Products Industries (16)

7- Cross-linking of Plastics	(EB)
8- Thermosetting Plastics	(MW) & (RF)

Wood Industries (25)

9- Curing of Wood/Resin Composites	(MW) & (RF)
10- Curing Composition Board Coatings	(UV)
11- Curing Composition Board Coatings	(EB)
12- Drying Coatings on Wood Paneling	(IR)
13- Drying of Coatings on Wood	(RF)
14- Wood Glueing	(RF)

LEGEND :
- MW = Microwave
- RF = Radio Frequency
- IR = Infrared
- UV = Ultraviolet radiation
- EB = Electron Beam

Paper and Allied Prods. Industries (27)

15- Processing of Wood Pulp Chips	(EB)
16- Paint Drying	(IR)
17- Curing of Packaging Coatings	(UV)
18- Laminating Paper Products	(RF)
19- Drying Paper Top Coatings	(IR)
20- Drying of Coatings on Paper	(RF)
21- Drying of Business Forms	(RF)

Printing, Publishing & Allied Ind. (28)

22- Curing of Ink	(UV)
23- Curing of Printed Materials	(EB)
24- Ink Drying on Paper	(IR)
25- Book Binding	(RF)

Primary Metal Industries (29)

26- Sand Core Processing	(MW) & (RF)
27- Curing Powder Coatings	(IR)

Fabricated Metal Prods. Industries (30)

28- Curing Sheet Metal Coatings	(UV)
29- Curing Sheet Metal Coatings	(EB)
30- Curing Coatings on Metal Products	(IR)
31- Drying Coatings on Sheet Metal	(IR)
32- Curing Coatings on Cans	(UV)

Chemical & Chemical Prods. Inds. (37)

33- Curing of Adhesives	(UV)
34- Curing of Adhesives	(EB)

Electric & Electronic Prods. Ind. (33)

35- Drying Major Appliance Coatings	(IR)
36- Ink Drying on Appliances	(IR)
37- Annealing of Semiconductors	(MW)
38- Curing Electronic Device Coating	(UV)
39- Curing Electronic Device Coating	(EB)
40- Curing Electronic Device Coating	(IR)
41- Curing Coatings on Magnetic Media	(EB)
42- Manufg. Optical Storage Media	(UV)
43- Curing of Wire Insulation	(EB)
44- Curing Coatings on Optical Fibres	(UV)
45- Curing of Wire Coatings	(UV)

Miscellaneous Industries

46- Curing of Plastisol Gaskets	(IR)
47- Curing & Tanning Hides & Leather	(EB)
48- Curing Fabric Coatings	(IR)
49- Dye Fixation	(IR)
50- Ink Drying on Fabric	(IR)
51- Drying Automotive Coatings	(IR)
52- Firing Vitreous Enamel	(IR)
53- Curing of Floor Coatings	(UV)

Table 3 - Food Industries -

Applications (SIC Code)	Meat Treatment (1011) (1012) (1021)	Radappertized Meats (1011)	Grain Disinfestation (1051)
Description of application	Elimination of microorganisms that cause spoilage and disease using EB radiation	Preparation of attractive meat products that may be stored at room temperature	Disinfesting grain with EB
How currently done in Industry ?	Often not done	No equivalent	Fumigants such as ethylene dibromide (EDB)
What Electrotechnology is used ?	Electron Beam with dosages in the range 50 - 400 kRAD	Electron Beam 3 - 5 MRAD	High energy Electron Beam
Industrial application status	Has been demonstrated. Pork and poultry approved in U.S.	U.S. Army NATICK Lab. developed	Two in Odessa (U.S.S.R.) (each 150 tons grain / hour)
Benefit(s) of the Electrotechnology	Extends shelf life of fish by reducing the number of spoilage organisms Eliminates trichina spiralis in pork Eliminates salmonella in poultry without heating and increases shelf life one week	Storable at room temperature and Attractive and appetizing : corned beef, beef steak, ham, pork chops and smoked turkey.	Eliminates need for chemical fumigants Total sterilization of insects leads to rapid extermination Effectiveness of 100% versus 80% for fumigation with EDB
Limitation(s) of the Electrotechnology	Consumer acceptance is the major concern. Health and Welfare approval not yet in place for meat. In poultry 150 - 400 kRAD treatment costs an estimated $0.05 / lb. Precautions regarding X-Ray emissions necessary Penetration depth.	To date use only in special cases such as : sterilized hospital meals space shuttle (astronauts) Not approved for general consumption Expensive to prepare Penetration depth.	Needs high throughput to justify the high capital cost Only suitable for treating thin layers of product Precautions regarding X-Ray emissions necessary Penetration depth.
R&D Needs	Investigate possible adverse effects of high dose processes.	Investigate possible adverse effects of high dose processes.	Investigate possible adverse effects of high dose processes.
Technology Transfer	Determine best approach to achieve consumer acceptance. EB product knowledge sheet.	Determine best approach to achieve consumer acceptance. EB product knowledge sheet.	Determine best approach to achieve consumer acceptance. EB product knowledge sheet.
Potential in Ontario (Number of Establishments)	(201) (35) (19)	(201)	(20)
References	[64] [83]	[64] [83]	[64] [83]
Allies	AECL, MacDonald College, Agriculture Canada, Nordion International Inc.	AECL, MacDonald College, Agriculture Canada, Nordion International Inc.	AECL, MacDonald College, Agriculture Canada, Nordion International Inc.

Table 3 - Food Industries (con't) -

Applications (SIC Code)	Decontamination of Spices (1098)
Description of application	Decontamination treatment of spices, onion and garlic powder
How currently done in Industry ?	Fumigation with ethylene oxide (EtO)
What Electrotechnology is used ?	Electron Beam 500 - 1000 kRAD
Industrial application status	Well developed (used in 16 countries) Spices are approved in Canada.
Benefit(s) of the Electrotechnology	Faster than treating with EtO Eliminates need for sample testing for quality control Avoids use of EtO which is toxic, mutagenic and carcinogenic.
Limitation(s) of the Electrotechnology	Precautions regarding X-Ray emissions necessary Penetration depth.
R&D Needs	Determine feasibility in Ontario. Investigate possible adverse effects of high dose processes.
Technology Transfer	Determine best approach to achieve consumer acceptance. EB product knowledge sheet.
Potential in Ontario (Number of Establishments)	May be applied to fruits & vegetables (127)
References	[64] [83]
Allies	AECL, MacDonald College, Agriculture Canada, Nordion International Inc.

Table 4 - Rubber Products Industries -

Applications (SIC Code)	Preheating/Vulcanization of Rubber (1521) (1598)	Vulcanization of Rubber (1521) (1598)
Description of application	Transformation of elastomers (rubbers) and sulphur into an elastic product within heating process	Improvement of properties of elastomeric or rubber materials by EB induced cross linking.
How currently done in Industry ?	Hot air/fluidized beds processes using mostly conventional gas-fired systems	Mainly tires, also conveyor belts.
What Electrotechnology is used ?	Microwave / Radio Frequency	EB radiation
Industrial application status	As of 1986, 1.5 MW (estimated) installed in Canada / U.S.	Apparently established.
Benefit(s) of the Electrotechnology	Thermodynamic & electromagnetic models predict a 90% reduction of the energy requirements : 4 to 11 MJ/kg product for conv. curing vs. 0.3 to 0.5 MJ/kg product for RF/MW curing. Based on a cost & economics model : curing costs reduced by 55% to 72% total finished costs reduced by 6% to 23 % Reduced srap. Increased production by 30 to 50 % MW ideally suited to difficult task of uniform heating of rubber.	Allows reduced component thickness which provides economic incentives. Elimination of waviness in tire reinforcing cords. Improved dimensional stability of: interliners, plies, bead cores, treads. Reduction of unsightly rubber projections on tire surface. Increased wet and dry skid resistance (2-9%).
Limitation(s) of the Electrotechnology	High capital cost (MW more than RF) High variation in MW related properties means adaptive design is required for every application and a specialist is needed for adjustements. As of 1986, dielectric loss character. of most of the materials were not readily available.	Wall thickness limitation. High capital cost.
R&D Needs	Temperature, power and time schedule controls optimization Special additives for better curing Porosity problems in vacuum curing	Continued research in EB accelerator beam propagation, maint. and control. Aging studies of EB vs. conventionally processed product.
Technology Transfer	Case studies of successful Ontario applications.	Case studies, dissemination of relevant patent information (1975-1979).
Potential in Ontario (Number of Establishments)	Canadian market penetration estimated at 58% in 2000. (14) (82)	(14) (82)
References	[17] [20] [27]	[24]
Allies	E.D.F (France), E.C.R.C (U.K.). Cober & Raytheon.	AECL

Table 5 - Plastic Products Industries -

Applications (SIC Code)	Cross-linking of Plastics (1611) (1631) (3381)	Thermosetting Plastics (1699)
Description of application	Improvement of properties of a wide range of polymers: wire insulation; shrink packaging mat'ls; poly. foams.	In heating/moulding process, irrever. change from fusible/soluble materials into infusible/insoluble resins.
How currently done in Industry ?	Chemical cross-linking using peroxides, moisture and heat.	Hot air/fluidized beds processes using mostly conventional gas-fired systems
What Electrotechnology is used ?	EB radiation	Radio Frequency / Microwave
Industrial application status	Apparently established.	As for 1986, 0.3 MW (estimated) installed in Canada.
Benefit(s) of the Electrotechnology	Improved product properties: Thermal stability Toughness High processing speeds (500-3000 ft/min) Cross linked foams: 10-40 times original volume closed cell construction.	Thermodynamic & electromagnetic models predict a 90% reduction of the energy requirements : 4 to 11 MJ/kg product for conv. curing vs. 0.3 to 0.5 MJ/kg product for RF/MW curing. Based on a cost & economics model : curing costs reduced by 55% to 72% total finished costs reduced by 6% to 23 % Reduced cure schedules mean increased production by 30 to 50 %
Limitation(s) of the Electrotechnology	Wall thickness limitation. High capital cost.	Transparent molds need to be Developed in order to use MW/RF processes. Microwave is more expensive than RF Adaptive design is required for every application, then a specialist is needed for adjustements. As of 1986, dielectric loss character. of most of the materials were not readily available.
R&D Needs	Comparison of properties of conventional and EB radiated polymers.	Fundamental research studies on MW/RF transparent molds.
Technology Transfer	Product knowledge sheet on EB.	
Potential in Ontario (Number of Establishments)	(48) (32) (31)	(405)
References	[24]	[20]
Allies	Raychem, Dupont, SPI.	SPI.

Table 6 - Wood Industries -

Applications (SIC Code)	Curing of Wood/Resin Composites (2592)	Curing Composition Board Coatings (2592)	Curing Composition Board Coatings (2592)
Description of application	Wood fibres or particles bonded together with thermosetting resin (i.e : phenol formaldehyde)	Particle board surface filled, coated, finish coated & exposed to UV radiation	Particle board surface filled, coated, finish coated & exposed to EB.
How currently done in Industry ?	Hot platen pressing with conventional fuel-fired systems	Traditional Method: Forced hot air or IR drying & solvent based coatings	Traditional Method: Forced hot air or IR drying & solvent based coatings
What Electrotechnology is used ?	Microwave or Radio Frequency	UV with 100% reactive coating systems.	EB with 100% reactive coating systems.
Industrial application status	As of 1986, one Microwave application identified in B.C. Some in Europe & U.S	Approx. 100 U.S. Companies Using U.V. & light curable coatings	2-3 U.S companies using EB
Benefit(s) of the Electrotechnology	Processing time reduced by 300 % with Radio Frequency equipment(output powers ranging from 250 kW to over 2500 kW) Thus, production increased by 30 to 50% Based on a cost & economics model : curing costs reduced by 55% to 72% total finished costs reduced by 6% to 23 % Manufacturer in B.C. reports better quality : product can be made in any length at an end product density 10% higher than ordinary structural wood beams.	Improved appearance, hardness and sanding properties More readily manufactured Low temperature operation: Avoids drying out substrate board Avoids rehumidification step Allows finishing of heat sensitive substrates (plastics, paper, pvc films) Fast cure times (seconds) - high production rates Essentially no volatile emissions (100kW power vs. 250kW for IR) Low operating cost/Less space required	Improved appearance, hardness and sanding properties More readily manufactured Low temperature operation: Avoids drying out substrate board Avoids rehumidification step Allows finishing of heat sensitive substrates (plastics, paper, pvc films) Fast cure times (< 1 sec.) - high production rates Essentially no volatile emissions Low operating cost/Less space required
Limitation(s) of the Electrotechnology	High capital cost. Microwave more expensive than RF	UV hazard. Cost of UV reactive coating materials. UV systems are viewed as being more complex and less forgiving.	X-Ray hazard with EB. EB has high capital cost which is justified only for very special products (heavily pigmented panels or low pressure laminates).
R&D Needs	Investigate approaches to lowering capital cost.	Long term Aging studies. UV processing equipment Development of new low cost radiation sensitive polymeric materials	Assess long term performance. EB processing equipment Reduction in coatings material costs New speciality products & markets.
Technology Transfer	Document the most successful application.	Document the most successful application.	Document the most successful application.
Potential in Ontario (Number of Establishments)	(12)	(12)	(12)
References	[17] [20]	[24]	[24]
Allies	MacMillan Bloedel, Forintek. E.D.F (France) E.C.R.C (U.K.)	MacMillan Bloedel, Forintek. E.D.F (France) E.C.R.C (U.K.)	MacMillan Bloedel, Forintek. E.D.F (France) E.C.R.C (U.K.)

Table 6 - Wood Industries (con't) -

Applications (SIC Code)	Drying Coatings on Wood Paneling (2521) (2592)	Drying of Coatings on Wood (25)	Wood Glueing (2543) (2611)
Description of application	A combined Infrared/Convection oven used to dry water based coatings on wood paneling production line	Drying of Coatings on Wood Substrates	Assembling wood products (furniture, windows, doors, framework,...) by glueing basic components.
How currently done in Industry ?	Hot air drying	Hot air convection process using conventional fuel-fired systems	Hot melt and air dry glues.
What Electrotechnology is used ?	Short wave Infrared / Convection	Air Flotation/Radio Frequency Assisted (ARFA) dryer	Radio Frequency
Industrial application status	Many U.S examples	Developed at the Electricity Council Research Centre (ECRC), UK	Many in Europe
Benefit(s) of the Electrotechnology	Dries coating from inside out thereby preventing skin formation & blistering Reduced energy costs Reduced capital costs Faster processing (+ 50%) Higher product quality Less floor space required Eliminated solvent emissions using water-based coatings Precise process control	In this field ECRC claims : Increased efficiency Reduced equipment length Subsequent energy and capital cost savings Product throughput increased Better product quality So far, lab. tests have indicated significant improvement in dryer efficiencies compared to conventional hot air dryer	Faster process (from hours to minutes) Less space requirements Energy savings (unquantified)
Limitation(s) of the Electrotechnology	Higher power requirement than UV and EB Product properties not as good as those using UV and EB.	High capital cost. New development - unproven equipment reliability.	Product specification : glues must be adapted to RF heating (urea-formol and vinyl-type glues are currently used) Electrodes must be correctly located for each wood configuration
R&D Needs	Quantify quality, cost and control advantages	Trial in industry	Document most successful european applications.
Technology Transfer	Document the most successful applications	Case studies of successful U.K application with expertise of E.C.R.C	Increase awareness of successful applications in Ontario by way of case studies of european examples
Potential in Ontario (Number of Establishments)	(18) (12)		(82) (237)
References	[17]	[17] [61]	[17] [27]
Allies	Impact Systems, Smart Controls.	E.C.R.C (U.K)	Radio Frequency Co., PSC Inc.

Table 7 - Paper & Allied Products Industries -

Applications (SIC Code)	Processing of Wood Pulp Chips (2711)	Paint Drying (2714)	Curing of Packaging Coatings (2731)
Description of application	Irradiate wood pulp chips to reduce insect and fungi losses and break down cellulosic components	Drying water-based paint on inorganic fibre ceiling tiles with Infrared tunnel oven	UV lamps used to cure liquid coating or liquid laminations for high gloss protected printing.
How currently done in Industry ?	Generally not done	Natural convection air dry	Oven & solvent-based varnishes; water based coatings; liquid & film laminat.
What Electrotechnology is used ?	Electron Beam	Long wavelength Infrared	UV radiation
Industrial application status	Some studies and experiments performed	One U.K application(uses 150 kW to dry 160 panels/h)	Hundreds of litho- and flexographic presses have UV lamp systems.
Benefit(s) of the Electrotechnology	Theoretical : Reduce consumption of chips by insects, fungi, etc. Reduce heat energy required in conversion to pulp Improve production and reduce unit cost	Relative to fuel-fired Infrared Option: Cleanliness Speed Lower capital cost Low energy cost Silent No combustion products Low maintenance Fast response (start and stop) Improved quality and fewer rejects (because of cleanliness) 3 month payback	Good quality Less energy. Fast. Eliminates/reduces solvent emissions.
Limitation(s) of the Electrotechnology	Question regarding competitive position relative to radioactive sources High capital cost.	Competition from gas-fired IR.	Cost of UV reactive coating materials. UV hazard.
R&D Needs	Quantify benefits Determine competitive position of EB relative to Cobalt 60 Determine optimum dose and dose rate	Quantify quality, cost and maintenance advantages	
Technology Transfer		Identify similar paint drying applications	Case studies of most successful applications.
Potential in Ontario (Number of Establishments)	(5)	This technology may be applied in other industrial sectors. (1)	(57)
References	[24]	[17] [68]	[24]
Allies	AECL (Whiteshell)	Impact Systems, Smart Controls.	Fusion Systems, Canrad-Hanovia, Fryston Canada.

Table 7 - Paper & Allied Products Industries (con't) -

Applications (SIC Code)	Laminating Paper Products (2791)	Drying Paper Top Coating (2791)	Drying of Coatings on Paper (2791)
Description of application	Lamination and drying of varnishes and water-based coatings on paper products	High intensity Infrared / Convection used to dry water or solvent based coatings on paper	Drying of Coatings on Paper
How currently done in Industry ?	Heated drum rollers or hot air convec. using conventional fuel-fired systems	Gas-fired IR / hot air convection.	Hot air convection process using conventional fuel-fired systems
What Electrotechnology is used ?	Radio Frequency	High Intensity Infrared/Convection	Air Flotation/Radio Frequency Assisted (ARFA) dryer
Industrial application status	As of 1986 : None in Canada European applications	Many U.S examples	Developed at the Electricity Council Research Centre (ECRC), UK
Benefit(s) of the Electrotechnology	Environment and operating cost advantg. due to elimination of dangerous and expensive solvents. Improved quality due to the consistency of the process Less maintenance	Drying time @ 45 m/min is < 1 sec Controlled closely using process conditions	In this field ECRC claims : Increased efficiency Reduced equipment length Subsequent energy and capital cost savings Product throughput increased Better product quality So far, lab. tests have indicated significant improvement in dryer efficiencies compared to conventional hot air dryer
Limitation(s) of the Electrotechnology	High capital cost.	Fragile elements. Competition with gas-fired IR.	High capital cost.
R&D Needs	Temperature, power and time schedule controls optimization	Quantify speed and control benefits	Field Trials. Comparison with IR process.
Technology Transfer	Case studies on most successful european applications.	Case studies on most successful applications.	Case studies of successful U.K application with expertise of E.C.R.C
Potential in Ontario (Number of Establishments)	(28)	(28)	(28)
References	[17]	[17]	[17] [61]
Allies	Paprican, E.C.R.C (U.K), E.D.F (France)	Paprican, E.C.R.C (U.K), E.D.F (France)	E.C.R.C (U.K), Greenbank Darvin.

Table 7 - Paper & Allied Products Industries (con't) -

Applications (SIC Code)	Drying of Business Forms (2792)
Description of application	Drying in the manufacture of standard continuous glued forms, data-mailers, continuous envelopes and similar work
How currently done in Industry ?	Conventional steam-heated drying cylinder
What Electrotechnology is used ?	Radio Frequency combined with conventional steam-heated systems
Industrial application status	As of 1986 : None in Canada Some in Europe
Benefit(s) of the Electrotechnology	RF use at end of drying provides : Better looking product (RF humidity profile correction avoids problem of 'tenting' while retains suppleness and flexibility along the glue line) Higher production speeds Better control of process (RF avoids overdrying) thus decreases production cost, energy costs and equipment size.
Limitation(s) of the Electrotechnology	RF drying process will be successful if the technique provides additional heating at carefully chosen locations on a paper machine
R&D Needs	Develop information on how to determine correct targets. Establish guidelines for application of Radio Frequency.
Technology Transfer	Case studies of successful european applications through help of E.C.R.C (UK) and E.D.F (France)
Potential in Ontario (Number of Establishments)	(38)
References	[17] [27]
Allies	E.C.R.C (U.K), E.D.F (France), PSC Inc. Strayfield Inc., Radio-Frequency Corp.

Table 8 - Printing, Publishing & Allied Industries -

Applications (SIC Code)	Curing of Ink (2731) (2831) (2841)	Curing of Printed Material (2831) (2839) (2841)	Ink Drying on Paper (2841)
Description of application	Curing of printed ink on paper: folding paperboard	High volume Printing Very high quality graphic arts applications	Drying black ink at web speeds of 180 m/min using two 50 kW banks of low mass Infrared tubes.
How currently done in Industry ?	Thermally cured (natural gas) or electric resistance.	Thermally cured (natural gas) or electric resistance.	Hot air drying
What Electrotechnology is used ?	UV radiation.	Electron Beam	Short Wave Infrared Long Wave Infrared and convection
Industrial application status	Over 300 installations: Majority in Offset, Silkscreen & some Flexographic.	Limited to specialty printing applications.	Oxford University Press (U.K) Toppan Printing Co. (Osaka, Japan)
Benefit(s) of the Electrotechnology	Dramatic reduction in unit cost.Compact Low cost (Capital & Energy) Increased production rates Elimination of solvent polution. Ease of maintenance. Product design flexibility. Elimination of blocking & Smearing in Multicolour Printing. Ink does not dry out in reservoirs. Less floor space required. Safer inks (high flash points). Rapid processing & fast delivery.	Speed Certain production techniques only achievable in this way.	Lower capital cost Reduced running costs (30% less than gas oven) Elimination of fire risk Reduced floor space Lower maintenance costs Improved control of heat transfer Reduced line stoppages Reduced material waste Avoids set off
Limitation(s) of the Electrotechnology	UV inks cost more than their conventional counterparts. UV hazard.	Relative to UV Radiation: Higher cost Larger Size Pollution	Competition with gas-fired IR.
R&D Needs	Quantify cost and production benefits.	Quantify cost and production benefits.	Quantify cost and production benefits Compare IR wavelengths for relative efficiency.
Technology Transfer	Document most successful applications	Product Knowledge sheet on EB.	Document successful applications
Potential in Ontario (Number of Establishments)	(57) (76) (183)	(76) (317) (183)	Significant in printing press lines (183)
References	[24]	[24]	[17] [68]
Allies	Fusion Systems, Canrad-Hanovia, Fryston Canada.	AECL.	Impact Systems, Smart Controls.

Table 8 - Printing, Publishing & Allied Industries (con't) -

Applications (SIC Code)	Book Binding (2831)
Description of application	RF dryers for sewn and perfect bound books to remove water from vinyl adhesives
How currently done in Industry ?	Conventional steam-heated drying cylinder
What Electrotechnology is used ?	Radio Frequency combined with conventional steam-heated systems
Industrial application status	As of 1986 : None in Canada Some in Europe
Benefit(s) of the Electrotechnology	RF use at end of drying provides : Better looking product (RF humidity profile correction avoids problem of 'tenting' while retains suppleness and flexibility along the glue line) Higher production speeds Better control of process (RF avoids overdrying) thus decreases production cost, energy costs and equipment dimension.
Limitation(s) of the Electrotechnology	RF drying process will be successful if the technique provides additional heating at carefully chosen locations on a paper machine
R&D Needs	Develop information on how to determine correct targets. Establish guidelines for application of Radio Frequency.
Technology Transfer	Case studies of successful european applications through help of E.C.R.C (UK) and E.D.F (France)
Potential in Ontario (Number of Establishments)	(76)
References	[17] [27]
Allies	E.C.R.C (U.K), E.D.F (France), PSC Inc. Strayfield Inc., Radio-Frequency Corp.

Table 9 - Primary Metal Industries -

Applications (SIC Code)	Sand Core Processing (2912) (2941) (2961) (2999)	Curing Powder Coatings (2921)
Description of application	Curing sand cores and drying ceramic washes in polystyrene molds in metal foundries	Cure electrostatically applied powder coatings on metal pipe and extrusions in an electric IR oven
How currently done in Industry ?	Oil or natural gas direct-fired conventional ovens	Gas-fired IR.
What Electrotechnology is used ?	Mainly Microwave, also Radio Frequency	Short wave IR.
Industrial application status	Limited use in Canadian Industry	Australia, USA., UK.
Benefit(s) of the Electrotechnology	Processing time reduced by up to 90% Labour costs reduced Quality improved (less scrap) Energy savings Plant space occupied is reduced Less heat and smoke generated	Absence of combustion products No solvent emissions Low maintenance requirements Absence of combustion products & convection current(high quality finish) Low capital cost (<1/2 of equiv. fuel fired oven) & lower operating costs Reduced floor area requirements Improved work environment Accurate temperature control, rapid heating, reduced rejects.
Limitation(s) of the Electrotechnology	Microwave more expensive than RF, but RF less flexible re product shape because relatively low power density. Competition from cold box cure.	Industry inertia. Cost of replacing functioning conventional equipment. Fragility and cost of IR emitters.
R&D Needs	Optimization of the use of binder systems and corebox materials Determine where less expensive RF systems may be used.	Modelling of powder coatings. IR heating interaction.
Technology Transfer	Prepare case studies of most successful applications.	Case studies of successful foreign applications
Potential in Ontario (Number of Establishments)	As of 1985, only 10% of industry uses microwave. (11) (52) (33) (60)	(20)
References	[17]	[17] [24]
Allies	Cober Electronics, Raytheon, PSC Inc. University of Waterloo, Queens.	Impact Systems, Smart Controls.

Table 10 - Fabricated Metal Products Industries -

Applications (SIC Code)	Curing Sheet Metal Coatings (3041)	Curing Sheet Metal Coatings (3041)	Curing Coatings on Metal Products (3041)
Description of application	Curing of Sheet Metal Coatings	Curing of Sheet Metal Coatings	IR curing of coatings : fabricated parts.
How currently done in Industry ?	Gas-fired, convection ovens, IR.	Convection ovens, IR, UV.	Convection ovens.
What Electrotechnology is used ?	UV radiation.	High energy electron beam curtain.	Short wavelength IR. (sometimes with convection)
Industrial application status	Very limited.	One major Japanese steel company (Nippon) using on metal coil stock	Diverse industrial applications
Benefit(s) of the Electrotechnology	Hypothetical(relative to thermal oven): 40% of first cost 10% of floor area 53% of processing cost Eliminates polution concern.	Hypothetical(relative to thermal oven): 10% of floor area 61% of processing cost Almost instantaneous start up. Actual: very fast to complete cure, cold cure, superior finish Elimination of solvent evaporation Unique properties:higher gloss, harder, improved chemical resistance, excellent stain resistance, excellent heat resistance. Curing essentially independent of pigment colour.	Relative to convection ovens : Absence of combustion products. Superior control Less floor space Reduced maintenance Increased throughout Increased capacity & efficiency relative to longwave IR
Limitation(s) of the Electrotechnology	Cost of coating materials. Concern re coating toxicity.	Same first cost as thermal (relatively high). No long term performance data. Oxygen content <700ppm in processing atmosphere is deirable. Formation of X-rays requires shielding Raw materials higher priced.	In direct competition with gas-fired Infrared
R&D Needs	Quantify benefits relative to thermal and other electrotechnology processes. Determine long term performance.	Determine long term performance.	Determine relative performance of different wavelengths.
Technology Transfer	Investigate possible european applications.	Document japanese example. Product Knowledge sheet on EB.	Document most successful applications
Potential in Ontario (Number of Establishments)	(177)	(177)	(177)
References	[24] [35]	[24] [64]	[17]
Allies	Fusion Systems, Canrad-Hanovia, Fryston Canada.	AECL.	Impact Systems, Smart Controls.

Table 10 - Fabricated Metal Products Industries (con't) -

Applications (SIC Code)	Drying Coatings on Sheet Metal (3041)	Curing Coatings on Cans (3042)
Description of application	IR drying of coatings on continuous strip sheet metal	Two or three piece cans have ink & over print varnish applied by roller and then cured by UV.
How currently done in Industry ?	Convection ovens, IR.	Gas-fired thermal treatment of volatile solvent or water-based coating.
What Electrotechnology is used ?	Infrared Radiation (primarily short wave length)	UV Curing (of 100% reactive inks, pigments, clear coatings).
Industrial application status	Established application	In use by Coors and American Can Co.
Benefit(s) of the Electrotechnology	Higher throughput Compact (lower building and conveying equip. costs) Lower first cost Efficient - surface rather than entire mass is heated Reduced operating costs Low maintenance Absence of air turbulence Better control (zoned). Used with standard paints & coatings	Solvent emissions eliminated 70% reduction in energy use relative to thermal curing Equipment cost 30% of alternate gas fired ovens 10% of floor space required by oven system. Lower maintenance
Limitation(s) of the Electrotechnology	Competition from gas-fired Infrared. Cost of replacement emitters.	UV inks are more expensive than thermally cured ink systems. Toxicity concern.
R&D Needs	Expand application range.	Need long-term performance information on UV cured metal coatings Quantify advantages of different coating systems.
Technology Transfer	Document most successful applications	Document most successful applications
Potential in Ontario (Number of Establishments)	(177)	(49)
References	[17] [35].	[17] [35].
Allies	Impact Systems, A.D. Smart.	Fusion Systems, Canrad-Hanovia, Fryston Canada.

Table 11 - Chemical & Chemical Products Industries -

Applications (SIC Code)	Curing of Adhesives (3792)	Curing of Adhesives (3792)
Description of application	Curing adhesives applied to pressure sensitive tapes and labels with UV.	Curing hot melts, pressure sensitive and laminating adhesives
How currently done in Industry ?	Thermally cured solvent based adhesive systems.	Thermally cured solvent based systems and IR.
What Electrotechnology is used ?	UV Radiation	Electron Beam
Industrial application status	Unknown.	Unknown.
Benefit(s) of the Electrotechnology	Could: Cost less to manufacture Exhibit improved performance 10% of capital costs 71% of operating costs	Solvents not required Improved efficiency Improved safety Eliminated or reduced air pollution Lower operating costs Rapid cure rate Catalysts and initiators are not req'd Improved process control Thermal post cure not required Outstanding adhesive properties: durability; adhesion; less shrinkages; reduced built-in stresses
Limitation(s) of the Electrotechnology	Cost of UV components.	Capital costs: 54% greater than thermal 15 times that of UV.
R&D Needs	Comparison with conventional systems.	Potential for curing composite structures
Technology Transfer		
Potential in Ontario (Number of Establishments)	(24)	(24)
References	[24]	[24]
Allies	EPRI.	AECL.

Table 12 - Electric & Electronic Products Industries -

Applications (SIC Code)	Drying Major Appliance Coatings (3321)	Ink Drying on Appliances (3321)	Annealing of Semiconductors (3352)
Description of application	Drying of coatings on major appliances using Infrared	Drying silk screened ink on home appliance control panels using IR generators	Pulsed Microwave energy is used to anneal the surfaces of silicon semi-conductors damaged by ion implantation
How currently done in Industry ?	Convection ovens, IR.	Undefined non-IR heating, likely convection oven	Pulsed lasers have been the more common approach to surface annealing
What Electrotechnology is used ?	Infrared Radiation (primarily short wave length)	Long wave Infrared Radiation	Microwave
Industrial application status	Established application	Applied at least once	Used experimentally
Benefit(s) of the Electrotechnology	Higher throughput Compact (lower building and conveying equip. costs) Lower first cost Efficient - surface rather than entire mass is heated Reduced operating costs Low maintenance Reduced labour (heat sensitive parts not removed) Absence of air turbulence Better control (zoned). Used with standard paints and coatings	Better control of process (to within 0.5 C). Elimination of rejected product.	Successful technique for semiconductor surface heating
Limitation(s) of the Electrotechnology	Line-of-sight heating limits application to simple shapes Competition from gas-fired IR.		Better control of process is required; i.e 1000C at +/- 10 C
R&D Needs			Annealing of gallium arsenide is currently investigated by Ontario Hydro with the help of University of Toronto. Improved heating control.
Technology Transfer	Demonstrate. Product Knowledge sheet.	Demonstrate if not widely used. Product Knowledge sheet.	
Potential in Ontario (Number of Establishments)	Appliance Manufacturing moving to pre-coated sheet (22)	(22)	(171)
References	[35]	[17]	[69]
Allies	Impact Systems, Smart Controls.	Impact Systems, Smart Controls.	Dept. of Metallurgy & Materials Science University of Toronto.

Table 12 - Electric & Electronic Products Industries (con't) -

Applications (SIC Code)	Curing Electronic Device Coating (3352)	Curing Electronic Device Coating (3352)	Curing Electronic Device Coating (3352)
Description of application	Curing coatings in printing circuit board & ICs, assembly and encapsulation of PCB's.	Curing coatings in printing circuit board & ICs, assembly and encapsulation of PCB's.	Curing coatings in printing circuit board & ICs, assembly and encapsulation of PCB's.
How currently done in Industry ?			
What Electrotechnology is used ?	UV radiation	EB radiation	IR Radiation
Industrial application status	Significant applications		
Benefit(s) of the Electrotechnology	General Benefits. Superior product production and performance Less floor space Greater line speeds Better energy efficiency (up to 80%) Easier to meet polution requirements Safer higher flash point materials No distortion of heat-sensitive substrates Unique manufacturing features	General Benefits. Superior product production and performance Less floor space Greater line speeds Better energy efficiency (up to 80%) Easier to meet polution requirements Safer higher flash point materials No distortion of heat-sensitive substrates Unique manufacturing features	General Benefits. Superior product production and performance Less floor space Greater line speeds Better energy efficiency (up to 80%) Easier to meet pollution requirements No distortion of heat-sensitive substrates Unique manufacturing features
Limitation(s) of the Electrotechnology	UV chemical cost	High capital cost.	
R&D Needs	Compare UV, EB and IR.	Compare UV, EB and IR.	Compare UV, EB and IR.
Technology Transfer			
Potential in Ontario (Number of Establishments)	(171)	(171)	(171)
References	[24]	[24]	[24]
Allies	Fusion Systems, Canrad-Hanovia, Fryston Canada.	AECL.	Impact Systems, Smart Controls.

Table 12 - Electric & Electronic Products Industries (con't) -

Applications (SIC Code)	Curing Coatings on Magnetic Media (3361)	Manufactg. Optical Storage Media (3361)	Curing of Wire Insulation (3381)
Description of application	Curing of coatings on magnetic storage media	Curing various layers in the manufacture of optical discs.	Curing (cross-linking) of polyethylene wire insulation.
How currently done in Industry ?	Mainly EB. Conventional used moisture cure polymer binder system	UV / some air dry curing.	Continuous thermal vulcanisation.
What Electrotechnology is used ?	EB radiation	UV radiation.	Electron beam.
Industrial application status	In use	In use and growing	Two examples sited.
Benefit(s) of the Electrotechnology	Instantaneous complete curing (replaces 2 week long process) Much more controllable method Better performing products Reduced wear of the coating and calendaring equipment Allows wider use of chromium dioxide magnetic pigment. Potential for one year payback.	Permits low cost production of optically read storage disc.	Six times greater linespeed (throughput). Half the energy cost per unit product. Half the operating cost per unit of product. Improved heat and cut-through resistance
Limitation(s) of the Electrotechnology	High capital cost.	UV chemical costs.	33% higher first cost. Insulation wall thickness limitation. Ozone and radiation environmental safety factors.
R&D Needs			Identification of conditions when EB should be applied.
Technology Transfer	Document successful applications.	Product Knowledge sheet.	Document successful applications.
Potential in Ontario (Number of Establishments)	(91)	(91)	(31)
References	[24]	[24]	[24]
Allies	AECL.	UV Chemical Suppliers.	AECL.

Table 12 - Electric & Electronic Products Industries (con't) -

Applications (SIC Code)	Curing Coatings on Optical Fibres (3381)	Curing of Wire Coatings (3381)
Description of application	Curing coatings on optical fibres.	Wire coatings for transformers, other small gauge electric wire. Insulation overcoat adds desired properties.
How currently done in Industry ?	Conventional hot air.	Gas-fired drying/curing ovens with toxic or high boiling point solvents
What Electrotechnology is used ?	UV radiation	UV radiation.
Industrial application status	In use and growing.	Apparently used in a number of applications
Benefit(s) of the Electrotechnology	Rapid cure. Elimination of solvent pollution. Compact.	Tough, flexible, highly cross-linked films Applied to bare or insulated wire Simple low cost equipment. 10 mils in one pass is easily attainable. Elimination of solvent pollution problems. High production line speeds Reduced energy use.
Limitation(s) of the Electrotechnology	Cost of UV materials.	Cost of UV materials.
R&D Needs		Quantify benefits.
Technology Transfer	Document most successful applications	Document most successful applications
Potential in Ontario (Number of Establishments)	(31)	(31)
References	[24]	[24]
Allies	Fusion Systems, Canrad-Hanovia, Fryston Canada.	Fusion Systems, Canrad-Hanovia, Fryston Canada.

Table 13 - Miscellaneous -

Applications (SIC Code)	Beverage Industries Curing of plastisol gaskets (1111)	Leather & Allied Prods. Inds. Curing & Tanning Hides & Leather (1711)	Primary Textile Industries Curing Fabric Coatings (1829)
Description of application	Curing plastisol gaskets that seal push-to-open beverage can tops using a conveyorized IR heater.	Irradiate fresh hides to cure and/or processed leather to tan	Crosslinking of polymers at elevated fabric and coating temperatures
How currently done in Industry ?		Curing by soaking in salt water (24hrs) Tanning by cross-linking polymer ctgs	Fuel fired Infrared
What Electrotechnology is used ?	Short wavelength IR heater.	Electron Beam	Infrared
Industrial application status	In use - North America?	Work mainly done by researchers to date	In use in Ontario
Benefit(s) of the Electrotechnology	800 pieces/minute	Elimination of much contaminated water produced in convent'l curing process Time saving : simultaneous curing and tanning For flat packaged hides appropriate dose may be applied at 100'/minute conveyor speed Energy saving	Space efficient Fast High thermal efficiency High uniformity and controllability
Limitation(s) of the Electrotechnology	Operating costs still more attractive for fuel-fired IR.	Electron accelerators impose thickness restrictions on leather packages undergoing processing Optimum for killing microorganisms (curing) may not be best dose for polymer cross-linking (tanning)	Often requires on-site or laboratory testing of the products and optimization of available equipment
R&D Needs	Identify & quantify differences between electric and fuel-fired IR systems.	Determine optimum radiation dose & best tanning polymers for optimum properties Can low energy electron treatment of both sides of hides cure successfully ?	Need to verify and quantify claimed safety, energy and controllability advantages
Technology Transfer	Document successful application.		Providing information on correct application and design of electric Infrared equipment
Potential in Ontario (Number of Establishments)	(57)	Greater in Alberta (15)	(33)
References	[17]	[64]	[17]
Allies	Impact Systems, Smart Controls, E.P.R.I.	AECL.	Impact Systems, Smart Controls.

Table 13 - Miscellaneous (con't) -

Applications (SIC Code)	Textile Products Industries Dye Fixation (1992)	Clothing Industries Ink Drying on Fabric (2434) (2444)	Transportation Equip't Inds. Drying Automotive Coatings (3231)
Description of application	Thermosolling of plastosoluble dyes onto polyester and reactive dye fixing onto cotton	Drying silk screened images on T-shirts travelling on a conveyor	Drying of coatings on auto bodies and other components using Infrared
How currently done in Industry ?	Soak in dye solution fixed with hot air or vapour.		Convection ovens, IR.
What Electrotechnology is used ?	Infrared	Infrared	Infrared Radiation (primarily short wave length)
Industrial application status	Demonstrated in laboratory.	In use in U.S.	Established application
Benefit(s) of the Electrotechnology	Laboratory experiments indicate for Thermosolling : 3 to 4 times faster; two orders of magnitude lower energy consumption Reactive dye fixing : good dyeing regularity; reduction in atmospheric pollution; faster; half the energy consumption.	Improved reliability Ease of maintenance Cleanliness	Higher throughput Compact (lower building and conveying equip. costs) Lower first cost Efficient - surface rather than entire mass is heated Reduced operating costs Low maintenance Reduced labour (heat sensitive parts not removed) Absence of air turbulence Better control (zoned). Used with standard paints and coatings
Limitation(s) of the Electrotechnology	Competition with gas-fired IR.	Competition with gas-fired IR.	Line-of-sight heating limits application to simple shapes The combination of convection and infra red drying used in many automotive applications tends to favour gas-fired Infrared
R&D Needs	Verification of laboratory results in full scale industrial process. Comparison of IR wavelengths.	Comparison of IR wavelengths.	Quantify competive position of electric Infrared. Comparison of IR wavelengths.
Technology Transfer		Document successful applications.	Case studies of most successful applications
Potential in Ontario (Number of Establishments)	(33)	(53) (7)	(15)
References	[17]	[17]	[17] [35]
Allies	Impact Systems, Smart Controls, E.C.R.C. (U.K).	Impact Systems, Smart Controls, E.C.R.C. (U.K).	Impact Systems, Smart Controls, E.C.R.C. (U.K).

Table 13 - Miscellaneous (con't) -

Non-Metallic Mineral Prods. Other Manufacturing Inds.

Applications (SIC Code)	Firing Vitreous Enamel (3562)	Curing of Floor Coatings (3993)
Description of application	A short wavelength IR furnace is used to fire vitreous enamel on badges.	Curing of urethane acrylic vinyl floor coatings.
How currently done in Industry ?	Gas-fired oven.	Low temperature thermal curing or isocyanate reactions.
What Electrotechnology is used ?	15 kW electric shortwave IR furnace.	UV Radiation
Industrial application status	In use - U.K.	Have made major impact.
Benefit(s) of the Electrotechnology	Higher quality product Improved control results in reduced Lost time & hazards Dust contamination reduced 90% Vitreous enamel wastage down nearly 50%.	Better abrasion, solvent and stain resistance in final product. Eliminate solvent emissions. Rapid cure. Compact.
Limitation(s) of the Electrotechnology	Competition with gas-fired IR.	High cost of UV coating materials.
R&D Needs		
Technology Transfer	Preparation of case study.	Document most successful applications.
Potential in Ontario (Number of Establishments)	(74)	(8)
References	[17]	[24]
Allies	Impact Systems, Smart Controls.	Fusion Systems, Canrad-Hanovia, Fryston Canada.

APPENDIX B

UV MATERIAL AND EQUIPMENT SUPPLIERS

UV MATERIAL AND EQUIPMENT SUPPLIERS

EQUIPMENT

Canrad-Hanovia Inc.
Fryston Canada Inc.
Fusion Systems Corp.
Research Inc.
Union Carbide

MATERIALS

Aceto Chemical Co.
Arco Specialty Chemicals
Celanese Chemical Co.
Ciba-Geigy Corp.
Diamond Shamrock Chemicals
Lord Corporation
Morton Chemical